Motion Analysis

PO-0252

TRUNK REFERENCE FRAMES AND THE CALCULATION OF TRUNK AND BREAST KINEMATICS IN HUMAN MOVEMENT ANALYSIS

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Introduction and Objectives: The use of the female cohort presents a unique challenge as the design of the bra used to support the breasts during physical activity compromises the positioning of the International Society of Biomechanics (ISB) recommended marker set used to create the trunk reference frame [1]. The need to develop a new trunk marker set has been highlighted [2] and should consider the location and design of the underband and bra straps; and other bra features such as neckline height. This study aimed to compare trunk and breast kinematics calculated using two existing and one new trunk marker set.

Methods: Following institutional ethical approval twelve females (mean (SD): age 23.8 (3.5) years, height 1.68 (.06) m, body mass 61.0 (5.8) kg, 32 to 34 underband with a B to D cup size) volunteered for this study. Eight trunk markers were used to define the three trunk reference frames (Figure) and an additional marker on the right nipple represented gross breast motion. Three dimensional movement of the markers were tracked using 15 optoelectronic cameras (Oqus, Qualisys, Sweden), positioned around the treadmill, sampling at 200 Hz. The participants stood statically in the anatomical position for a 2 second trial for use in the segment estimation algorithm before running bare-breasted at 2.8 m/s. Marker coordinates were recorded for five gait cycles. Markers were identified and reconstructed in Qualisys Track Manager; no data interpolation was used as marker capture success was utilised in this study to assess the suitability of each marker set. Marker coordinates from both the static and dynamic bare-breasted trials were imported into Visual 3D (C-Motion Inc, USA) and the three trunk reference frames (segments) were created. To simulate the underband when wearing an everyday or sports bra [3] both the PX and T8 markers (Figure) were removed from the raw data files (dynamic trials). These modified files were imported into Visual 3D where it was noted that the Trunk 2 segment failed to be constructed due to an insufficient number of markers, limiting its use during trials that include females wearing a breast support garment. Trunk segment capture success (%), segment origin instability (cm), segmental residual (cm), trunk kinematics (°) and breast ROM (cm) relative to each trunk segment, were calculated for the three trunk segments.

Results: Segment capture success varied from 88 % to 100 % depending on the marker set. Segment origin instability ranged from 1.5 cm to 0.2 cm, which represented up to 35 % of superio-inferior breast ROM. Maximum trunk extension differed by 7° depending upon the marker set used and finally breast ROM varied by 41 % in the anterioposterior (A-P), 54 % in the mediolateral (M-L), and 21 % in the superioinferior (S-I) direction (Table).

Figure:

Figure: Marker locations on the trunk segment used to define the trunk reference frames
(Trunk 1 - STN, RRIB, LRIB; Trunk 2 - STN, PX, C7, T8; Trunk 3 - STN, PX, C7, T8, STN33, C750)

Conclusion: Key findings show that Trunk 1 marker set achieved less than 100 % capture success and was also the marker set with the greatest origin instability. Qualitative inspection of optoelectronic data suggests that arm swing during running tended to alternately obscure the rib markers reducing capture success. Furthermore the majority of origin instability occurred in the superioinferior direction, possibly due to motion of the subcutaneous fat at the distal marker locations used for the Trunk 1 segment. Trunk segments with markers restricted to the anterior aspect of the trunk (Trunk 1) caused a backward tilt of the trunk segment relative to the global vertical axis. Within the local coordinate system of the trunk, this tilt altered the directional distribution of the breast. Trunk 2 marker locations (PX, T8) are obscured by a bra's underband therefore preventing its use when female participants are wearing breast support garments. The Trunk 3 marker set maximises capture success and minimises origin instability whilst also having sufficient markers to avoid obstruction from current bra designs and arm swing mechanics. This trunk marker set is recommended when investigating trunk and breast kinematics using the female cohort during running with and without breast support.

Table:

Marker Set	Segment Capture Success (%)	Origin Instability (cm)	Segment Residual (cm)	Trunk Maximum Tilt (°)	Trunk Maximum Flexion / Extension (°)	Trunk Maximum axial rotation (°)	Breast A-P ROM (cm)	Breast M-L ROM (cm)	Breast S-I ROM (cm)
Trunk 1	88	1.5	0.5	-3.5	-5.8	-13.2	3.9	3.5	4.3
Trunk 2	100	0.2	0.4	-4.1	7.9	-18.5	2.6	1.8	5.2
Trunk 3	100	0.2	0.4	-4.1	8.0	-19.4	2.3	1.6	5.0

Caption: Table: Breast and trunk kinematics

References: [1] Wu et al., J. Biomech, 38: 981-992, 2005.
[2] Mills et al., J. Biomech, 47: 2606-2610, 2014.
[3] Scurr et al., J. Sports Sci, 28: 1103-1109, 2010.

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